The effect of sequentially changing background color during target detection

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United States
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THESIS

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ABSTRACT

This experiment investigated the effect of sequentially changing the background color during target detection. Two color sequences, three speeds, and twenty-four subjects were used on an experimental apparatus designed and built at the Naval Postgraduate School. A three-way factorial analysis of variance was used to analyze the data. It appears that both the sequence of background colors and the speed at which the color changes have an effect on target detection time.

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I. INTRODUCTION

Radar, and the associated target detection, has been under constant study since its operational employment in World War II. Initially, cathode-ray tubes were coated with a double-layer cascade (long-persistence) phosphor. The background color and the target color were determined by the chemical composition of the phosphors and the usual amber-colored optical filters employed at the time (Fink, 1947, 539-540). Phosphor technology has increased to the point where it is now possible to have different background colors (Feldman, 1958) and different target colors (U. S. Army ECOM Report, 1967). Target detection in recent years has centered on the size, shape, and color of the target.

Green and Anderson (1956) studied the search times for different colored targets on a constant background. Smith (1962), Jones (1962), and Gould (1968) studied color coding and reported that background color was immaterial as long as a certain threshold background-target contrast was maintained. In the above studies the background color was constant during a particular search task and was only changed between search tasks. These results did not preclude the possibility that sequentially changing the background color during a particular search task could reduce the detection time.

Therefore, it was decided to design an experiment that could investigate the effects of sequentially changing the background color on a simulated radar screen.

II. METHOD

A. APPARATUS

The basic experimental apparatus was designed and built by Dr. G. K. Poock, R. C. Smith, and J. C. Brown (Fig. 1). It consisted of two main parts: the Target Presentator and the Background Determinator (Fig. 2 and 3).

The Target Presentator consisted of a rotating metallic silver screen perforated forty times and covered by frosted glass. Only thirteen of the forty perforations were backed by light sources and could actually project an image onto the frosted glass. Eleven of these projected irrelevant symbols (circles and triangles) and the other two projected the target symbol (rectangle). Only one of the target symbols could be projected at a time and between two and ten irrelevant symbols were visible at all times. The irrelevant symbols were electrically controlled by a motor-driven series of cams. The set of cams allowed the irrelevant symbols to be projected on the screen in a pseudo-random manner (Fig. 4).

The screen rotated at approximately 5.17 revolutions per minute and irrelevant symbols were projected on the frosted glass for about 8.6 seconds. After being off for about 3.0 seconds the symbols were reprojected and this continued for an entire experimental session. Therefore, irrelevant symbols were projected on the frosted glass

Figure 1. Experimental Apparatus

Figure 2. Background Determinator

Figure 3. Target Presentator

Figure 4. Drive Mechanism of Target Presentator

on an average of one every second (Fig. 5-7). The projection of the target symbol was controlled by the experimenter with a remote micro-switch. In addition to causing the target symbol to appear on the frosted glass, the noiseless micro-switch also activated a noiseless electrical timer. The target symbol rotated around the simulated radar screen until the subject pressed the detection button located on the right side of the Target Presentator apparatus which stopped the electrical timer and turned off the target symbol. The determination of which target symbol to present to the subject was made by the experimenter setting a switch located in the Target Presentator and accessible through a hole located in the rear of the apparatus.

The Background Determinator consisted of a light source and a three-color wheel. The light source was a 150-watt light bulb and the three-color wheel was made of plexiglas covered with three different colors (Red, Blue, and Green) of theatrical gel (Fig. 8). The color wheel rotated at three different speeds (9.53, 7.84, and 6.58 RPMs) and its direction of rotation could be changed making it possible to project the two different sequences (Red-Green-Blue and Red-Blue-Green) of color onto the metallic silver screen.

B. SUBJECTS AND TEST SITE

The experiment was performed in the Human Engineering Laboratory at the Naval Postgraduate School (NPS). The twenty-four subjects were all male officer students from NPS. Their ages varied

Figure 5. Presentation Screen

Figure 6. Presentation Screen raised to show Symbol Projection Assembly

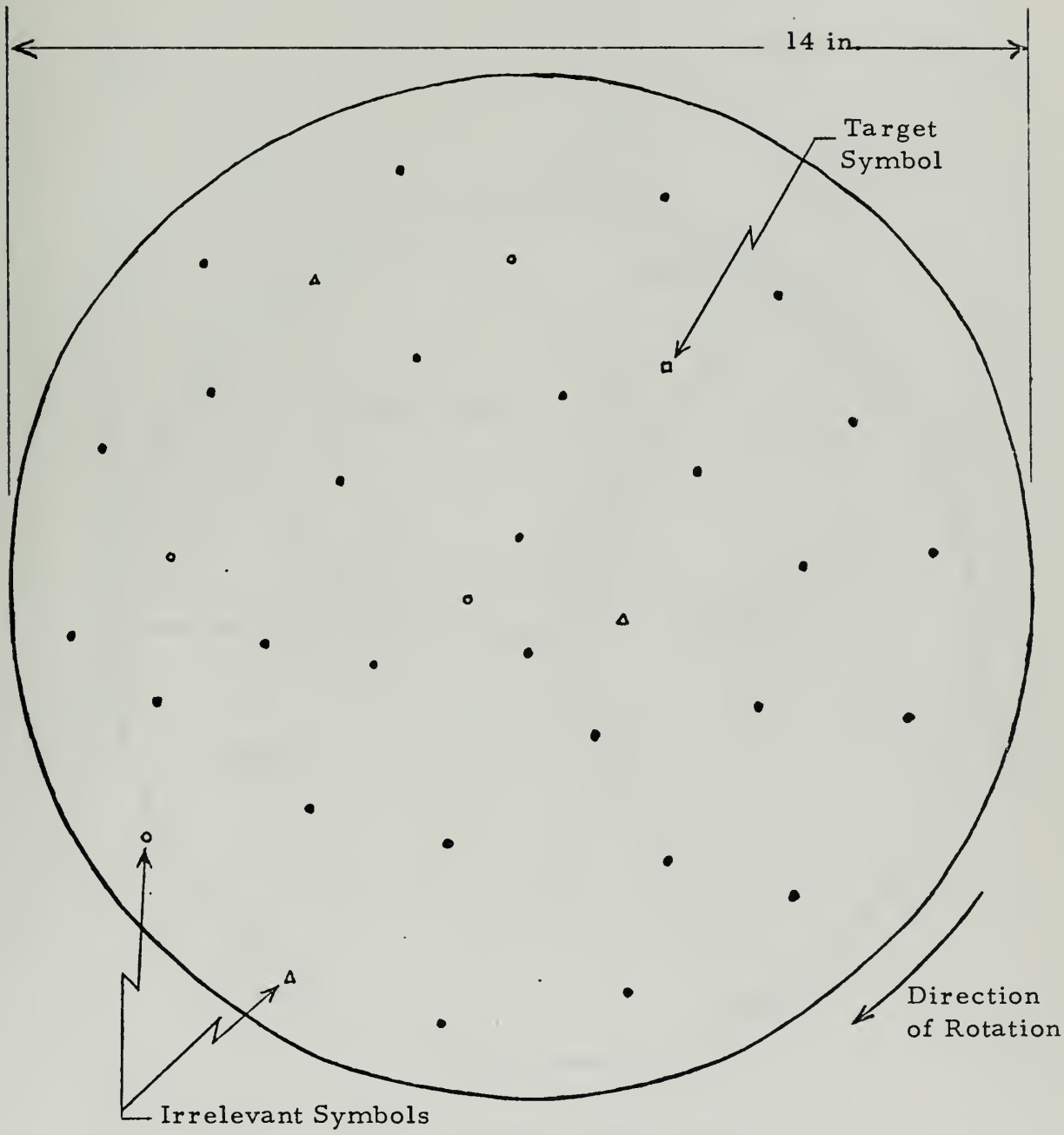

Figure 7. One Example of Symbols on Simulated Radar Screen (all symbols 1/16 in.)

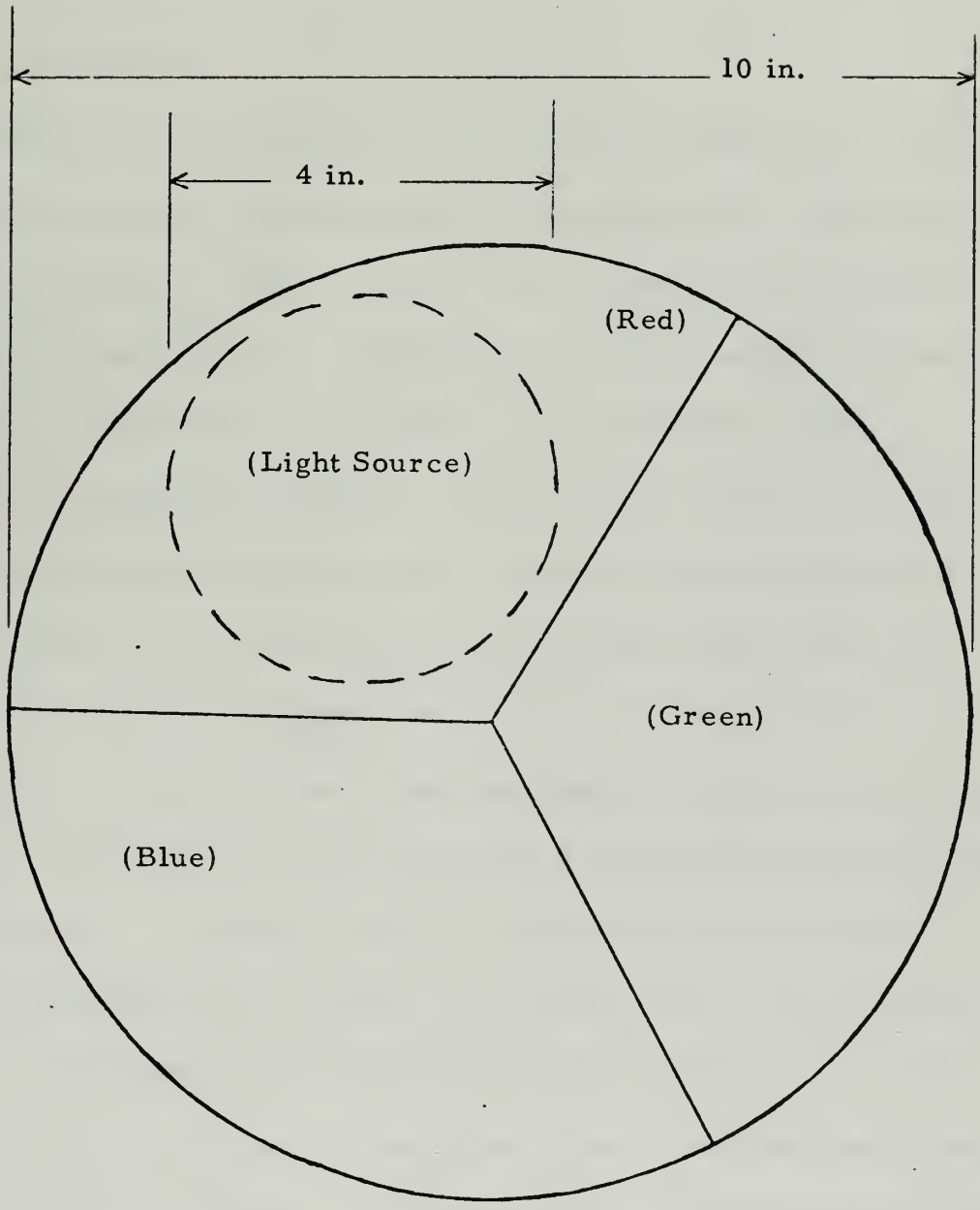

Figure 8. Three-Color Wheel

between 25-34. Those who habitually wore glasses were required to wear them during the experiment.

C. PROCEDURE

Subjects were given standard instructions (Appendix A). Before beginning the actual experimental session each subject performed a number of practice trials to insure that he knew what he would be looking for and what to do during the actual experiment. Each subject performed a total of twelve trials: the six treatments (table I) in a particular sequence followed by a replication in that same sequence.

The twenty-four subjects were broken down into eight groups of three subjects each. Each group was presented with a particular sequence of treatment application as shown in table II to insure that the effects being studied were not confounded by a possible learning effect. For instance, subjects in group 2 were first presented with the sequence ...red.blue.green... with increasing speeds (Slow-Med.-Fast) followed by the sequence ...red.green.blue... with decreasing speeds (Fast-Med.-Slow) whereas the subjects in group 7 were presented with the sequence ...red.green.blue... with decreasing speeds followed by the sequence ...red.blue.green... with increasing speeds.

The decision on which of the two possible target symbols to present to the subject was made by the experimenter on a random basis for each of the twelve trials.

TABLE I

FACTOR LEVELS

Color Sequence	
...Red-Green-Blue...	1__
...Red-Blue-Green...	2__
Speed of Color Change	
28.59 changes/min. (Fast)	__1
23.52 changes/min. (Med.)	__2
19.74 changes/min. (Slow)	__3

Example:

Treatment 23 - Sequence Red-Blue-Green at 19.74 Color changes per minute.

TABLE II

SEQUENCE OF TREATMENT APPLICATION

	Sequence of Application					
Group	1st	2nd	3rd	4th	5th	6th
1	11	12	13	21	22	23
2	11	12	13	23	22	21
3	13	12	11	21	22	23
4	13	12	11	23	22	21
5	21	22	23	11	12	13
6	23	22	21	11	12	13
7	21	22	23	13	12	11
8	23	22	21	13	12	11

IV. RESULTS

The linear statistical model assumed for this experiment was:

$$X_{ijk} = \mu + S_i + Q_j + SQ_{ij} + D_k + SD_{ik} + QD_{jk} + SQD_{ijk} + e_{ijk}$$

where

X_{ijk} is target detection time,

μ is the true mean for all observations,

S_i is the effect due to the different subjects,

Q_j is the effect due to the different sequences,

D_k is the effect due to the speed of color change,

e_{ijk} is the random experimental error.

The other terms represent interactions between factors. This is a mixed model with one random factor (Subjects) and two fixed factors (Sequence and Speed).

In testing the hypotheses that there is no sequence effect, no speed effect, no subject effect, and no interactions, a three-way mixed model analysis of variance was used (Dixon, 1970) to analyze the observed data (Appendix B).

As shown in table III, two hypotheses could be rejected: sequence has no effect on detection time and speed has no effect on detection time. None of the other hypotheses could be rejected and it was concluded that only the sequence of background colors and the speed at which the background colors changed affected detection time as

TABLE III

ANALYSIS OF VARIANCE ON DETECTION TIME

Source of Variance	Degrees of Freedom	Mean Square	"F" Ratio
Subjects(S)	23	4.40526	1.16
Sequence(Q)	1	15.08815	7.93**
S x Q	23	1.90285	0.50
Speed(D)	2	17.56078	5.88**
S x D	46	2.98356	0.79
Q x D	2	0.02023	0.01
S x Q x D	46	2.65322	0.70
Error(e)	144	3.80055	
Total	287		

**Significant at p=0.01

measured on the experimental apparatus. Subjects appeared to have little effect on detection time and all interactions were negligible.

Although the speed of background color change was found to be significant, the mean detection times at the slow (19.74 color changes/min.) and the medium (23.52 color changes/min) speeds were not significantly different (table IV).

Figure 9 is a graphical representation of the effects of changing the speed and sequence of background colors. Figures 10 and 11 are frequency histograms showing the distribution of detection times. The overall mean detection time was 3.97 seconds.

TABLE IV

DUNCAN MULTIPLE RANGE TEST

	Speed (Color changes/min.)		
Factor Level	28.59	23.52	19.74
Mean Detection Time	3.495	4.325	4.090

Standard Error = 0.199

p	2	3
Range	2.77	2.92
LSR	.551	.581

Test			
	28.59 vs 23.52	=	0.830*
	28.59 vs 19.74	=	0.595*
	23.52 vs 19.74	=	0.235

*Significant at p=0.05

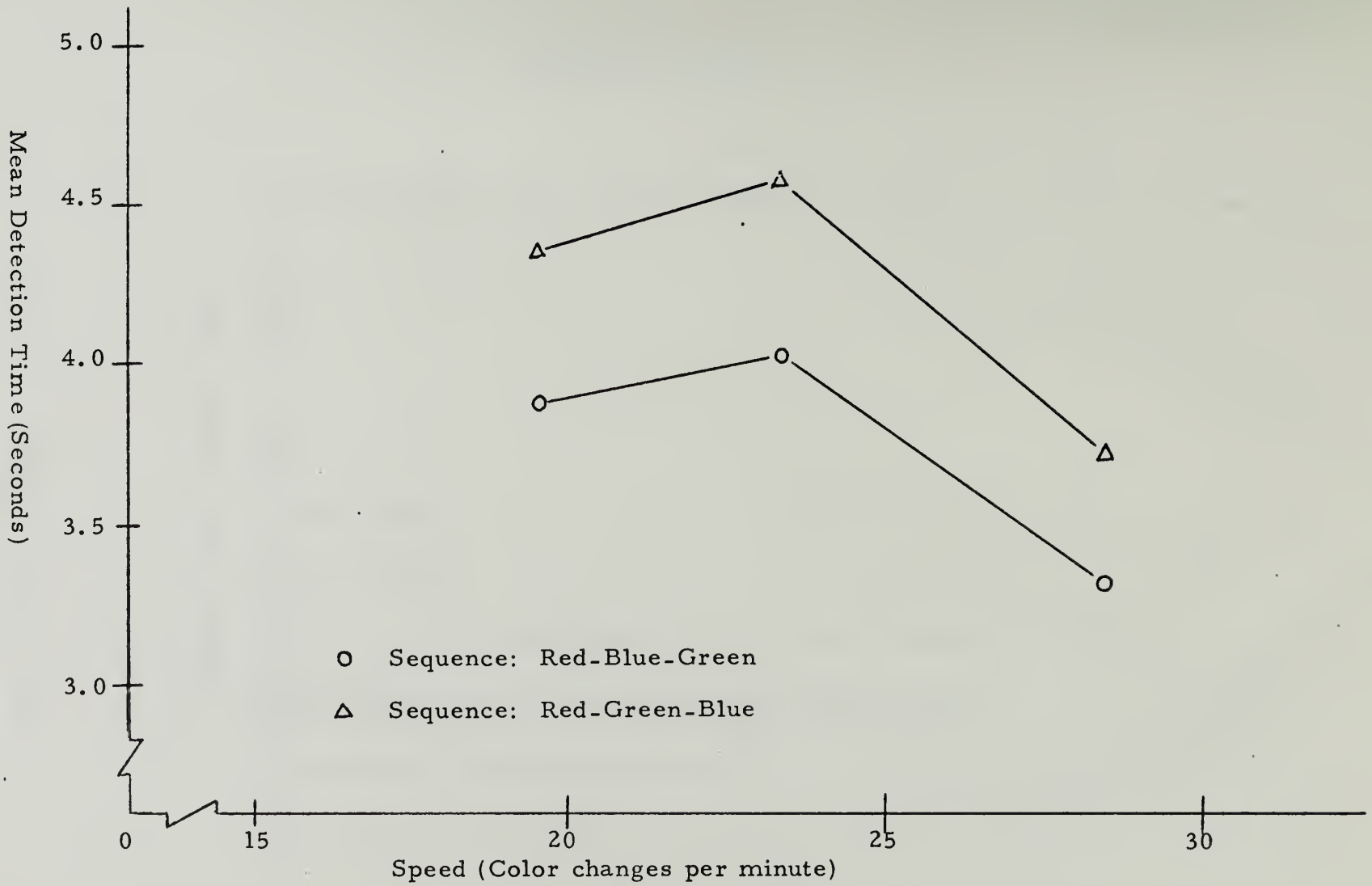

Figure 9. Mean Detection Time Graph

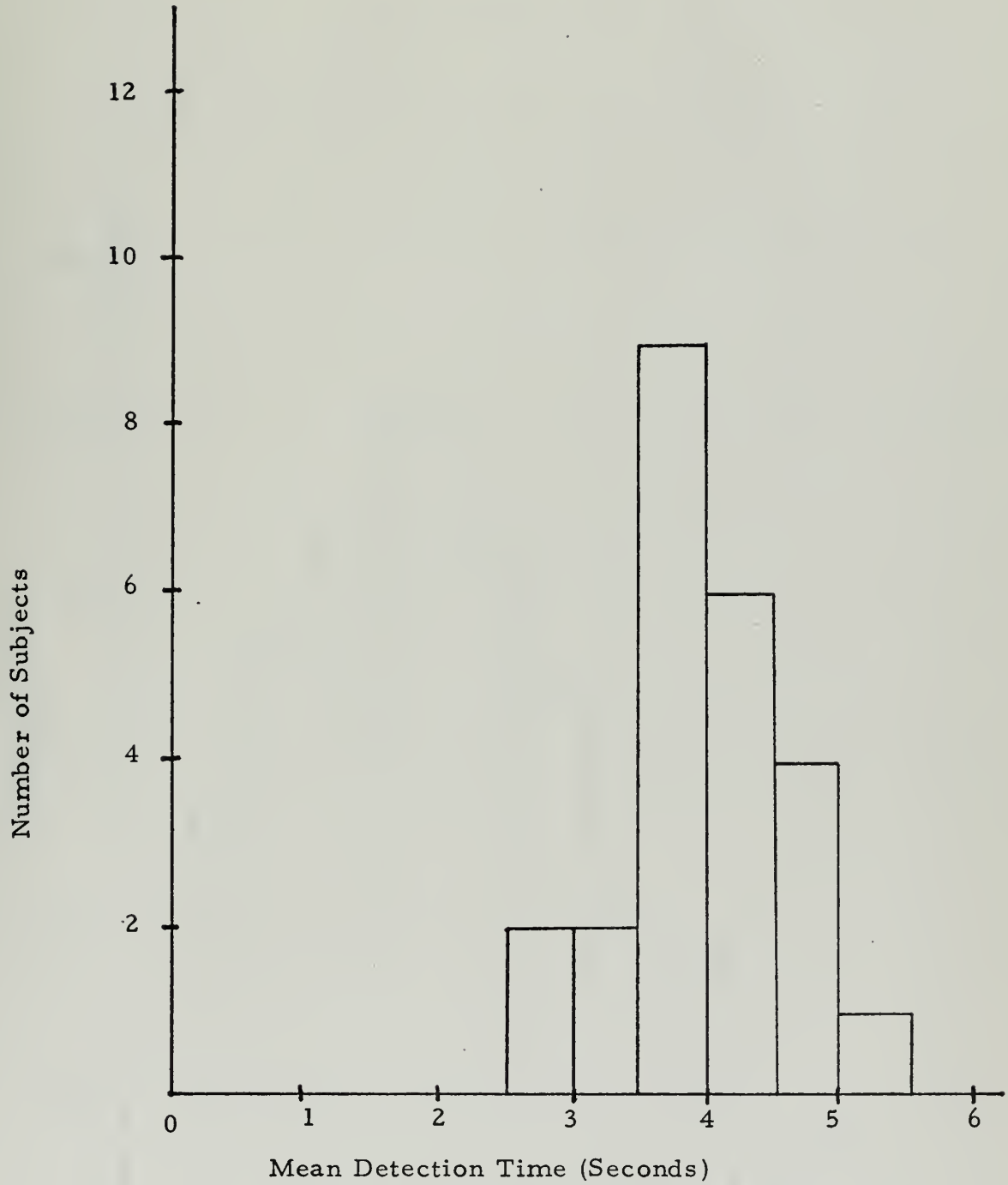

Figure 10. Subject Detection Times

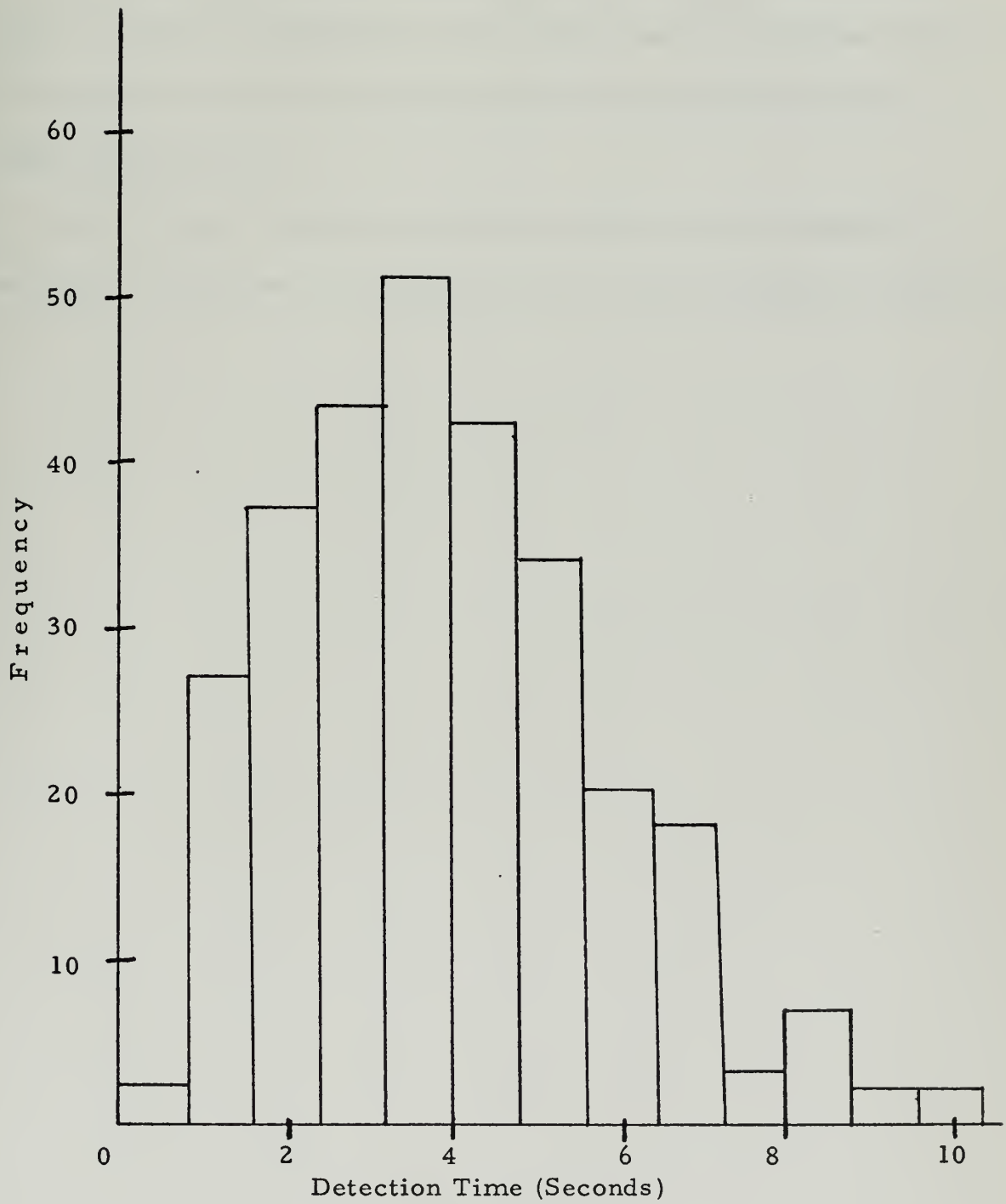

Figure 11. Detection Times

IV. DISCUSSION

In the experimentation reported here, it was found that both the speed at which the background color changed and the particular sequence of background colors presented had statistically significant effects on target detection time.

Since only two sequences and three speeds were investigated it is felt that both the speed and sequence effects must be further investigated.

APPENDIX A

INSTRUCTIONS TO SUBJECTS

The experiment in which you are about to participate measures the time it takes you to locate a particular symbol on a simulated radar screen under various conditions.

As you can see, there are numerous dark circles moving behind the screen. At times during the experiment, lights will go on and off behind some of these dark circles projecting a geometric figure ...either circular, triangular, or rectangular... on the screen. (A short demonstration was presented to acquaint the subject with the movement and shape of the symbols.)

During the experiment you are to stand directly in front of the apparatus looking down on the screen with your right hand resting on the right side of the top with one finger resting on this button. (The subject was shown the button and properly positioned.) When you detect a rectangular-shaped symbol press the button. When you press the button the symbol will disappear. You are simulating the activity of a well-trained operator. Therefore, if you push the button for the wrong symbol please notify me in order that the trial may be attempted again.

APPENDIX B

SUMMARY OF OBSERVED DATA

	RED-GREEN-BLUE (Speed)			RED-BLUE-GREEN (Speed)		
Subject	Fast	Med.	Slow	Fast	Med.	Slow
1	3.18	3.60	2.88	2.24	5.75	3.20
	3.40	3.84	5.14	2.72	2.53	6.32
2	2.38	4.60	2.17	1.19	6.80	2.63
	1.36	9.50	6.33	1.95	1.22	5.01
3	5.75	3.10	5.19	1.45	3.30	1.10
	1.65	2.52	2.01	2.45	3.16	1.20
4	1.20	7.62	1.48	2.84	1.16	8.30
	5.00	2.80	3.20	6.58	1.40	0.58
5	2.75	8.63	6.16	1.16	3.12	2.18
	5.15	3.01	4.32	4.42	5.42	3.64
6	4.53	4.30	3.30	3.62	2.30	4.38
	2.41	2.58	4.60	3.71	3.60	3.00
7	3.80	3.38	8.68	5.68	3.62	3.75
	4.12	4.00	4.44	3.24	3.08	4.60

8	1.22	2.20	4.20	2.15	3.68	5.20
	3.42	4.10	6.04	2.29	4.14	5.15
9	3.30	4.36	3.33	4.52	5.32	2.40
	2.30	6.84	8.63	1.90	2.56	4.62
10	5.16	5.32	6.45	4.18	4.86	3.36
	1.60	3.80	4.57	4.46	3.18	3.84
11	0.85	9.77	9.89	2.60	4.00	2.43
	3.95	5.37	2.99	4.56	5.96	6.90
12	4.80	5.14	2.88	2.16	6.90	2.33
	6.15	8.66	4.35	8.66	2.22	6.82
13	8.91	3.65	3.23	6.33	6.18	3.73
	3.48	5.14	6.85	1.45	2.74	6.03
14	2.39	3.79	4.85	0.78	2.48	2.31
	4.46	3.06	3.54	1.54	7.36	5.12
15	3.17	5.41	3.48	2.19	1.37	3.40
	3.83	6.98	2.71	5.04	3.48	5.20
16	2.17	4.80	1.59	3.13	4.18	2.31
	1.96	5.23	3.08	1.25	2.39	2.58
17	3.36	5.30	2.10	4.80	5.60	4.23
	7.29	3.24	5.90	2.05	4.24	3.83

18	4.68	3.00	2.55	1.46	3.15	2.04
	6.77	4.05	1.84	5.07	4.56	6.65
19	6.54	4.24	8.62	1.96	6.09	1.92
	4.25	1.05	4.23	6.08	1.70	3.71
20	3.86	2.30	3.25	5.56	6.81	4.32
	3.57	3.84	6.68	2.17	5.24	6.90
21	1.53	1.45	3.72	5.00	5.39	6.00
	2.86	6.11	1.26	1.45	6.11	1.62
22	4.78	2.55	5.09	4.21	2.86	4.50
	4.22	2.27	3.86	3.37	4.54	3.02
23	6.41	4.94	5.19	4.30	6.61	3.46
	1.98	5.76	3.31	4.08	6.14	4.82
24	3.72	6.43	3.62	1.97	5.25	1.30
	2.33	5.28	3.90	1.60	2.51	2.94

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13. ABSTRACT

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